THE USE OF REPEAT TERRESTRIAL PHOTOGRAPHY IN THE STUDY OF LANDSLIDE HAZARDS

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ABSTRACT

A photograph from the Dominion terrestrial photogrammetric survey in 1928 by M.P. Bridgland contributed to a study of a landslide that occurred on the south shore of Brazeau Lake in Jasper National Park in 1933. The newly created Bridgland Repeat Photography website, at http://bridgland.sunsite.ualberta.ca/ contains 2 sets of 735 photographs of Jasper National Park, the original set of photos taken in 1915 and the repeat set of photos taken in 1999. We used these photos to look for signs of slope movement in the Colin Range, Jasper National Park. We found evidence of rock fall and debris flow.

The photos proved worthwhile as a reconnaissance of the area, and for identifying areas of movement and stability within the 84 years between the original set and the repeat set of photographs.

As repeat photography projects become more frequent, it is likely that these databases will provide an opportunity to extend the study of landscape changes over a longer period of time, thus learning more about how landscapes change and the time period over which they change. While air photos may prove more useful in the last 50 years, as there is a much more comprehensive database of airphotos, repeat photography projects are useful in studying landscape changes, either on their own, or else in conjunction with air photo interpretation over time periods over twice as long.

RESUME

Cruden (1982) a utilizé une photo originèlle de l'arpente photogrammetrique terrestre de Dominion en 1928 par M.P. Bridgland, pour etudier un éboulement qui a pri place sur la rive sud du lac Brazeau au park National Jasper en 1933. La nouvelle website, Bridgland Repeat Photography a http://bridgland.sunsite.ualberta.ca contient 2 groupes de 735 photographes du Parc National Jasper, le premier groupe a été pris en 1915, et l'autre en 1999. On a utilizé ces photos pour détecter des indices de mouvement de pente dans les rangées Colin, parc National Jasper. On a trouvé l'évidence de roches tombées et d'écoulement de débris.

Les photos sont provées invaluable pour la reconnaissance du terrain, et pour identifier les sites de mouvement et stabilite durant les 84 ans entre le premier et deuzième groupe de photos.

Parce que ces projets de photographie répetitive deviennent plus nombreux, c'est probable que ces bases d'infomation on donnes la chance d'étendir l'étude de changements dans le paysage pendant une durée plus longue, ét d'apprendre comment le paysage change et la durée sur laquelle les changements prennent place. Tandis que les photos aériennes sont plus utiles pour les études des dernières 50 ans parce que la base de ces photos aériènnes est beaucoup plus compréhensive, les projets de photographie répétitive sont utiles pour étudier les changements du paysage, sois par eux mèmes, ou en conjonction avec les photos aériènnes pour des périodes de temps plus de deux fois plus longues.

1.0 INTRODUCTION

Surveyors such as M.P. Bridgland and David Thompson conducted much early mapping in the mountainous regions of Canada. They went into places with no maps, and created the early maps of areas that are now widely available for our use. They used several different tools in creating the early maps of these areas.

M.P. Bridgland was a surveyor for the Dominion Lands Survey, and in 1915 he undertook the task of creating the first topographic map of Jasper National Park, created as a forest reserve in 1907 (Parks Canada, 2000). Bridgland took a total of 735 photographs in his survey in 1915 (Higgs, 2001). In 1998 and 1999 Higgs and Rhemtulla of the University of Alberta repeated all 735 of the photographs that were taken by Bridgland (Higgs, 2001).

This paper considers the usefulness of photography from the Bridgland Repeat Photography Project in the assessment of landslide hazards, where a hazard is defined as "a condition with the potential for causing an undesirable consequence" (IUGS Working Group, 1997). We attempt to expand this analysis to other repeat

photography projects that may be available, either at the current time or in the future.

The usefulness of these prints is discussed for types of slope movement that have been documented from the ground. The three main types of slope movement discussed here are toppling, exfoliation, and debris flows. The repeat photographs are available in digital form on the Bridgland Repeat Photography website at http://bridgland.sunsite.ualberta.ca/. The area that is used in this analysis is the west facing portion of the Colin Range, Jasper National Park. Landslide nomenclature in this paper follows that of Cruden and Hu (1996) and slope nomenclature follows that of Cruden (1989).

2.0 RECENT SLOPE MOVEMENTS AND THE PHOTOS

Hincks spent the summer of 2002 in the Colin Range of Jasper National Park mapping slope movement phenomena. Modes of movement that were observed within the area include toppling and rock fall, exfoliations and debris flows. Specific locations of these phenomena are highlighted on sets of the Bridgland photos to determine whether or not the repeat photos are useful in the determination of landslide hazards (Hincks, 2003). Figure 1 is an airphoto showing areas where slope movements occur within the Colin Range of Jasper National Park.

Figures 2 and 3 are a set of repeat photos from the Bridgland collection, showing the north part of the area in Figure 1. The figure was composed using two photographs from the Bridgland collection, creating a panoramic photograph of the area in both 1999 and 1915. The photographs are then examined in detail in the areas where rock fall is known to occur.

From the photographs it can be seen that the vegetation in the area has changed over the 84-year period between the sets of photographs. As vegetation can be an indication of landslides, the vegetation changes can be used to analyze landslide hazards with repeat photographs.

2.1 Toppling

Active toppling is observable in numerous areas of the Colin Range of Jasper National Park, on cataclinal, anaclinal and orthoclinal slopes

The main location of toppling on cataclinal slopes is along the west facing slope of the Colin Range, where the Athabasca River cuts the range at an angle that is oblique to the geological structure of the area. Figures 2 and 3 cover the majority of this area that is currently experiencing toppling on cataclinal slopes. For the most part, from the observation of these photos, the presence of toppling blocks on these slopes can not be seen. However, the 1999 photographs do show areas where there is no vegetation. These are areas where toppling is occurring on these slopes. Yet, these locations are not the only locations on this slope where toppling occurs.

Garrone Creek is an area of active toppling on orthoclinal slopes. Garrone Creek is located between Hawk Mountain and Mount Colin on the west facing slope of the Colin Range. This is the creek that is located near the centre of the photographs in Figures 2 and 3. Again, the presence of active toppling can not be readily determined from these photographs. Again, this area appears as unvegetated in the 1999 photographs, yet a change in the slope can not be determined from these photographs.

Toppling on anaclinal slopes occurs on the east facing slopes of the Colin Range, which are not visible on Figures 2 and 3. From other photographs that have been examined within the Bridgland collection, changes due to anaclinal toppling can be seen along the creek that runs along the west face of Hawk Mountain. Changes were observed using Corel Draw, creating layers for both of the photographs, which were overlapped. New layers were added, where the slope profile was traced on the 1915 photograph, and a fourth layer was created to trace the slope profile on the 1999 photograph. The two slope profiles were then compared, showing a change in the slope profile, indicating that at least one large block moved from the slope, with the most likely mode of movement being toppling. This slope was determined to be anaclinal from geological maps and personal observations.

2.2 Exfoliation

Exfoliation has occurred at two locations. The first location was on the west facing slope of Morro Peak, within the Devonian Palliser Formation, near the base of the slope. The other location where exfoliation was noted to occur was on the face of Mount Colin within the Palliser Formation limestone as well.

Both exfoliations were noted to occur near the base of steep cataclinal underdip slopes, formed in steeply-dipping, bedded sedimentary rocks. This mode of movement can not be observed on aerial photographs, due to the nature and the locations of the movement. This mode of movement is found to occur under ledges along the cataclinal underdip slopes, leaving the appearance of a solid slope from above. Yet exfoliations can be observed on terrestrial photographs (Figure 4).

Figure 1 – The west slope of the Colin Range, Jasper National Park, showing areas of exfoliation, E; orthoclinal toppling, O; cataclinal toppling, C, anaclinal toppling, A and debris flow deposits, DF, overlain on part of aerial photograph A23025-138, Natural Resources Canada. Scale 1:60 000.

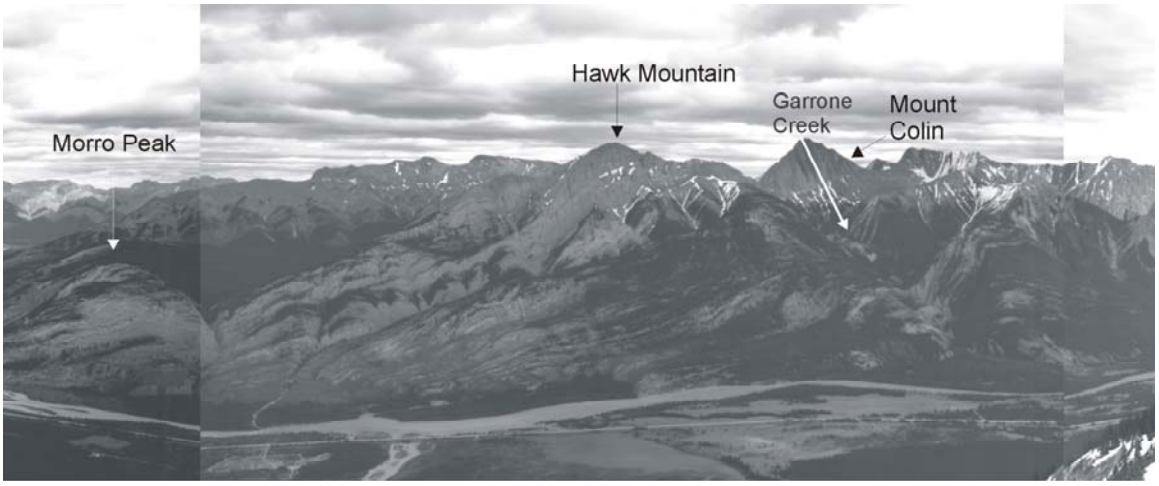

Figure 2 – Higgs and Rhemtulla repeat photograph numbers 470 and 471.

Figure 3 – Bridgland photograph numbers 470 and 471.

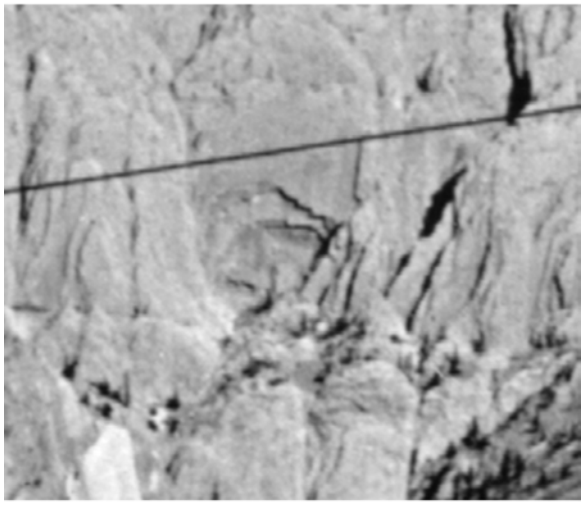

Figure 4 – A portion of Bridgland's photograph 485 showing exfoliation on the west of Morro Peak.

2.3 Debris Flows

Periodic debris flows in colluvial material were documented at the south end of the west slope of the Colin Range, along an unnamed creek. The authors propose to name this creek Debris Flow Creek. Documentation of the occurrence of debris flows at this location can be found in Dougherty (1991). This creek is used as the approach to many different alpine climbs, and Dougherty states "This hike used to be quite straightforward until heavy rain in July 1989 dramatically changed the character of the canyon" (pg. 292). The nature of the change within the canyon is not mentioned within the book, yet from this information and observations within the valley, it is likely that a debris flow was triggered by the heavy rains.

As can be seen in the set of photographs of Figures 5 and 6, the vegetation in the area of Debris Flow creek has changed over the 84 year time period. This change is especially noted on the alluvial fan of the creek. Minor changes can be observed in this area between the two photos. The first area where slope movement can be inferred is the area on the north side of the creek, where vegetation is not present on either of the photographs. This is an area of colluvial deposits which are constantly being reworked by the creek and by further mobilization of the colluvium under gravitational forces. This area is one of the main contributors to the periodic debris flows that occur at this location.

Another area where change can be observed on these photographs is the area where the creek cuts through the till deposits, left from the retreat of the Athabasca Glacier (Mountjoy, 1974). The till face on the south side of the alluvial fan has been altered between 1915 to 1999. This change is easier to see when the photos are enlarged as digital files, and compared closely.

3.0 DISCUSSION

Photography taken by Bridgland of the west shore of Brazeau Lake in 1929 has been used by Cruden (1982) to establish conditions before the 1933 Brazeau Lake slide.

The Bridgland Repeat photography project is a unique tool, with many potential applications. Changes in land use and in vegetation cover have been discussed using the repeat photography project. The question is whether or not repeat terrestrial photogrametric surveys are useful in the analysis of landslide hazards.

Since the introduction of aerial photography in Canada by the 1920's, these photos have proved useful in the analysis and quantification of landscape changes (Natural Resources Canada, 2002). Prior to the use of aerial photography, topographic maps of a areas of high relief were compiled from data acquired using photographic surveys. Phototopography was a common method used by surveyors, and was used for the mapping of the Selkirk Mountains (Wheeler, 1905), and the mapping of Jasper National Park (Higgs, 2001). The Geological Survey of Canada had 13 000 square miles of British Columbia and Alberta mapped by D.A. Nichols, F.S. Falcolner, K.G. Chipman, W.H. Miller, R. Bartlett and A.C.T. Sheppard between 1904 and 1923 (Thompson, 1967). Over the period 1886 to 1906 and 1911 to 1923, the Dominion Land Survey had McArthur, King, Wheeler, Bridgland, A.J. Campbell and R.E. Harris map 20 950 square miles (Thompson, 1967). The British Columbia government also had 6 474 square miles mapped by R.D. McCaw and G.J. Jackson between 1913 and 1923 (Thompson, 1967). In addition, the Alaska-British Columbia border was mapped using the phototopographic method by the International Boundary Commission and the Geodetic Survey, Department of the Interior (Thompson, 1967). Other photographic surveys were taken after this list (used by Thompson, 1967) had been compiled by Bridgland in 1923. Given that phototopography was the preferred method of mapping mountainous terrain from 1887 to 1930, there are extensive and comprehensive photographs of many areas of Canada, which predate aerial photography by up to 50 years.

Another advantage of using oblique terrestrial photography is the range of views that are available. Within the Bridgland collection, there are several stations that contain photographs of the southwest-facing portion of the Colin Range. The use of differing angles of photographs leads to a more encompassing view of the area that is being studied. In addition, the use of differing viewpoints may illuminate aspects in shadows, or aspects that are obscured by intervening objects.

One benefit of the Bridgland collection of repeat photographs is the digital database of photographs, with 1000 DPI scans of both the original and the repeat

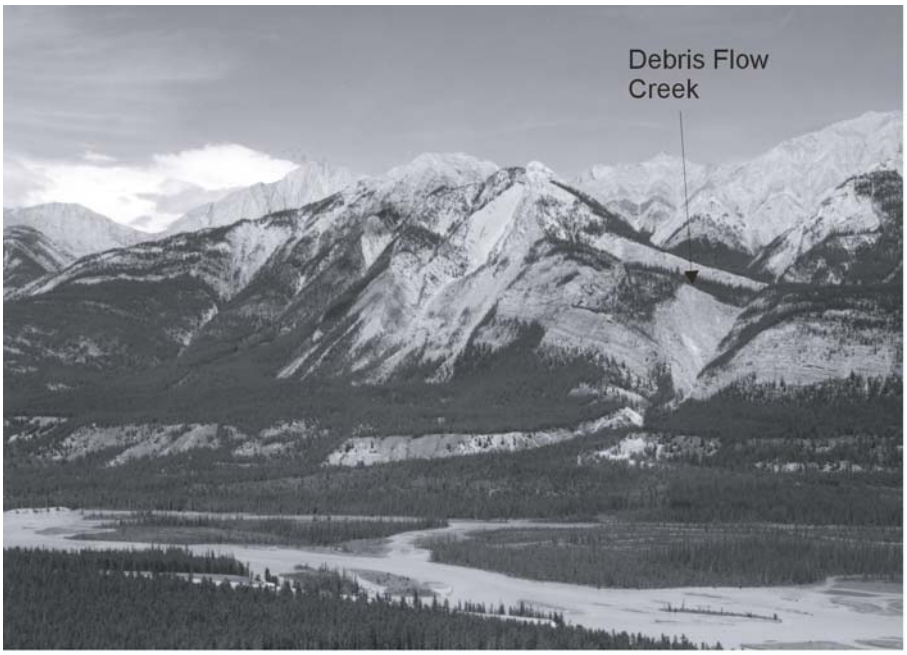

Figure 5 – Higgs and Rhemtulla repeat photograph number 460 showing the area of Debris Flow Creek. The canyon of the creek can be noted by the lack of vegetation, and the lateral moraine is present in the foreground of the photograph.

Figure 6 – Bridgland photograph number 460 showing the area of Debris Flow Creek. The north wall of the canyon can be noted by the lack of vegetation, and the lateral moraine of the Athabasca Glacier is present in the foreground of the photograph, and is cut by the creek.

photographs. These digital images can be enlarged and manipulated with respect to the tone and the contrast of the photograph. Photographs can also be imported into programs like Corel Draw and Adobe PhotoShop, where comparisons of the photographs can be made in great detail. The photographs taken in 1915 by M.P. Bridgland are of great detail, to the point where individual bedding planes can be observed when the photograph has been enlarged (as in Figure 4).

One difficulty in the use of these photographs, as with aerial photographs, arises from the different light conditions that are present at the time of the photographs, and the inconsistency of the tone and the contrast of the photographs, not only from the original set to the repeat set, but also the differences within photographs taken at the same time from the same station number. This is illustrated in Figure 2.

4.0 CONCLUSIONS

In the case of smaller slope movements, such as toppling and exfoliation, changes may not be readily visible to the naked eye. However, as digital collections of repeat photography become more readily available, repeat photography projects are likely to be useful in reconnaissance studies. Areas that remain active are often shown by a lack of vegetation, and can be further examined on the ground, based on areas of interest identified on repeat photos. With the increase in the sophistication of digital photography, digital databases of repeat photographs will increase in quality, and prove to be able to detect smaller changes.

One other application of the repeat photography projects includes identifying areas that are subject to repeated and periodic slope movements, as documented with Debris Flow Creek. The area of Debris Flow Creek is one that is visible in both the original and the repeat photographs as an area which is hazardous.

Oblique photographs also prove useful for identifying areas of slope movement that are not visible from aerial photographs, such as exfoliations.

Generally the landslide hazard on the trails paralleling the foot of the Colin Range on the east side of the Athabasca River is low. There are areas of higher hazard on the Range above which could usefully be explored in more detail as public exposure to the hazard rises.

While repeat photography is not yet an exact science, the information that can be gained from oblique terrestrial photographs that were taken before aerial photographs were available can prove to be useful in reconnaissance studies, and in identifying area of potential slope failure, or else areas that require further study.

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6.0 REFERENCES

Atlas of Canada. 2001. The Territorial Evolution of Canada. http://atlas.gc.ca/maptexts/map_texts/ english/ carte1905_e.html

Bridgland, M.P., 1924. Photographic Surveying, Bulletin 56, Topographical Survey of Canada, Ottawa.

Cruden, D.M. 1982. The Brazeau Lake Slide, Jasper National Park, Alberta. Canadian Journal of Earth Sciences, 19: 975-981.

Cruden, D.M. 1989. The Limits to Common Toppling. Canadian Geotechnical Journal, 26: 737-741.

Cruden, D.M. and Hu, X.Q. 1996. Hazardous Modes of Rock Slope Movements in the Canadian Rockies. Environmental and Engineering Geoscience, Vol. II(4): 507-516.

Dougherty, S. 1991. Selected Alpine Climbs in the Canadian Rockies, Rocky Mountain Books, Calgary. 320p.

Higgs, E. 2001. The Bridgland Repeat Photography Project: About: Photographs. http://bridgland.sunsite.ualberta.ca/html/photo.html

Hincks, K.D. 2003. Some Modes of Movement on slopes in the Colin Range, Jasper National Park. M.Sc. thesis in preparation.

IUGS Working Group on Landslides, Committee on Risk Assessment. 1997. Quantitative risk assessment for slopes and landslides – The state of the art in: Cruden, D.M. and Fell, R (eds) Landslide Risk Assessment. A.A. Balkema, Rotterdam, Netherlands, 3-12.

Mountjoy, E.M., 1959. Geology Miette, Alberta. Geological Survey of Canada, Map 40-1959, Ottawa, scale 1: 126 720.

Mountjoy, E.M. 1964. Geology Mount Robson, Alberta British-Columbia. Geological Survey of Canada, Map 47-1963, scale 1:126 720.

Mountjoy, E.M. 1974. Maligne Canyon – A Story of water erosion since the retreat of the glaciers. Special Report #2, Jasper National Park, Jasper.

Mountjoy, E.M. and Price, R.A. 1976. Geology of Medicine Lake, Alberta; Geological Survey of Canada, Open File 372, scale 1:50 000.

Mountjoy, E.M. and Price, R.A. 1985. Geology of Jasper, Alberta; Geological Survey of Canada, Map 1611A, scale 1:50 000.

Parks Canada, 2000. Japer National Park – History of the National Park. www.worldweb.com/ParksCanada-Jasper/history/parkage.html.

Thompson, D.W., 1967. Men and Meridians, Queens Printer, Ottawa, Volume 2, 334p.

Wheeler, A.O., 1905. The Selkirk Range, Government Printing Bureau, Ottawa, 459 p.